COOPERATIVE U.S./EUROPEAN RESEARCH ON COMMAND AND CONTROL SYSTEM INTEROPERABILITY

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INTRODUCTION

A number of European and U.S. Organizations are currently engaged in joint research to identify, develop and demonstrate automated command and control applications using embedded computer resources and computer-controlled communications systems. The specific organizations involved in the effort reported in this paper include the U.K. Royal Signals and Radar Establishment (RSRE), the U.S. Defense Advanced Research Projects Agency (DARPA), The Norwegian Defense Research Establishment (NDRE), University College London (UCL), the German Air and Space Research Establishment (DFVLR) and the Norwegian

Telecommunications Agency Research Establishment (NTARE). It is expected that the Italian CNUCE Institute will also participate in this work during calendar year 1983, along with two Canadian Defense Research Establishments in Ottawa (DREO) and Halifax, Nova Scotia (DREA).

A principal objective of this cooperative effort is to adapt or develop and use the latest computer communications technology to explore opportunities for improving the effectiveness of national and NATO command and control. Some of the primary technologies being utilized include packet switching, electronic message systems, interactive graphics, integrated digital voice/data systems and distributed database and operating system techniques. Concerns for interoperability, applicability of national and international standards to military systems, performance, robustness under hostile conditions and security and access control color the particular bilateral and multilateral experiments being conducted in the course of this research work.

In the following sections, a brief description of the activities and objectives of the participating organizations are outlined and a few of the experimental efforts are discussed by way of summarizing the scope of this cooperative program.

DARPA

The U.S. Defense Advanced Research Projects Agency's Information Processing Techniques Office has been engaged in a continuing initiative to develop and demonstrate techniques for applying advanced information processing technology to a variety of command and control problems. A primary result of this effort has been the development of several new computer communication techniques based on the concept of packet switching. The primary motivation of this work has been to improve the utilization of scarce commnication resources needed to support command and control and to develop ways in which both voice and data requirements can be satisfied with common digital switching and transmission facilities. The ARPANET, based on high speed (50 Kb/s) land lines and miniprocessor or microprocessor packet switches, was the first of the systems developed by DARPA to explore ways of controlling the allocation of digital transmission capacity more dynamically.

The ARPANET has been in operation since approximately 1969 and now incorporates about 100 switching nodes and 300 computers. In the mid-1970's, several new packet communication research projects were initiated including packet satellite to support long-haul voice and data communications and packet radio to support mobile, tactical computer

communication. In addition, work was started to develop or use local area network packet switching to support high speed, low delay communication for intra-building, intra-ship, or intra-platform voice/data systems.

The packet satellite technology research led to the establishment of an Atlantic Packet Satellite Network (SATNET) as an experimental vehicle for studying the dynamic allocation of satellite transponder capacity among many ground stations, each requiring access to a high capacity channel for short, intermittent periods. The demands of the traffic sources were such that conventional allocation techniques (e.g. time-division derived circuits) were not very effective at achieving high system utilization. In the mid- to late- 1970's, DARPA, the British Post Office, the Norwegian Defense Research Establishment and the Norwegian Telecommunications Agency, along with University College London, Bolt Beranek and Newman, COMSAT Corporation and Linkabit Corporation (the latter three being U.S. contractors) developed and tested a variety of dynamic packet allocation methods capable of supporting both packet voice and data services in the SATNET. Since approximately 1980, the SATNET has been the primary packet network by which the participants in the cooperative research program have carried out their work.

In addition to carrying out research in packet communication networking, DARPA has also been pursuing techniques for the interconnection of a wide range of packet networks, including public data networks, so as to make combinations of these technologies useful for specific military applications. The principles behind this "internetting" research effort are the development of a communication protocol architecture, gateways for network interconnection and specific protocols to provide reliable, end-to-end communication among a heterogeneous set of computer systems (i.e. multi-vendor computers and operating systems). At stake is the ability for complex and highly robust multi-network systems to be constructed and managed and evolved while enhancing opportunities for interoperability among many different networks and systems. Much of this work has been carried out with the cooperation and active participation of the various agencies and organizations mentioned in the introductory paragraphs of this paper. The Internet System, which incorporates the SATNET, ARPANET, countless local networks, several packet radio networks (in the U.S.), and national, international and private packet networks in North America and Europe, is one result of this cooperative activity. The details of this system are presented in a companion paper on the U.S. Department of Defense Internet Architecture.

The U.S. Defense Communications Agency has taken a major role in the transfer of the internetting technology developed, in part, in this cooperative effort, to the rest of the U.S. Department of Defense. In another companion paper, the standardization of the protocols and architecture of the Internet System by the Defense Communications Agency, on behalf of the U.S. Department of Defense is outlined along with the procedures developed for achieving its primary packet network and application computer system interoperability objectives.

In addition to the basic data networking initiatives, DARPA and its cooperating partners in Europe have been pursuing techniques for reducing the bandwidth required to support integrated packet voice/data communications. A variety of low data rate packet speech algorithms have been explored and many implemented and tested. Of particular note is the Linear Predictive Coding algorithm (LPC) which has been implemented at very modest cost by the U.S. MIT-Lincoln Laboratory using state-of-the-art very large scale integration methods. In concert with the Defense Communications Agency and other organizations within the Department of Defense, DARPA is now establishing a broadband version of the packet satellite technology, using a domestic 3 megabit per second satellite channel. This wideband channel network represents a major effort to demonstrate the potential economies of supporting both voice and data applications on a dynamically-allocated packet satellite channel serving many independent, cooperating ground stations. The wideband system is integrated into the internet architecture and is available to support research into combined voice/data command and control applications of interest to the NATO countries.

Along with the combined voice/data research, DARPA has also been pursuing methods for integrating voice, facsimile, text and graphics communication into a common electronic message system framework. This effort requires the development of low-cost work stations with bit-map displays, voice encoding and decoding capabilities, facsimile scanning and reproduction and interactive graphics composition and editing. Experimental protocols and application software for the support of this type of command and control technology have been developed and are being used to evaluate new concepts in the context of the interoperability requirements and internetworking requirements which are of increasing importance to all NATO countries faced with an increasingly automated battlefield environment.

The U.S. Naval Electronics Systems Command (NAVELEX) is pursuing a research and development program, called METANET, which incorporates many of the detailed protocols and architectural components of the

Internet System. Under joint DARPA and NAVELEX support, a Navy version of the packet satellite technology called MATNET has been developed, using a channel of the U.S. FLTSATCOM satellite system. In conjunction with NDRE and RSRE, and other participants in the cooperative command and control research program, NAVELEX has sponsored a number of demonstrations of the use of packet communication for command and control. In particular, NAVELEX has concentrated on integrated data/voice conferencing and interactive graphics support for command and control applications. This technology is expected to be installed for regular experimental use aboard the newest U.S. aircraft carrier, the Carl Vinson.

DFVLR

The Deutsche Forschungs und Versuchsanstalt fuer Luft- und Raum-fahrt (DFVLR) has recently joined the SATNET/Internet community of users in cooperation with the other participants in the command and control research program. In its capacity as a major research center for the application of satellite technology to civil and military requirements of the German Ministry of Defense, the DFVLR is extremely interested in identifying and demonstrating new opportunities for the use of satellites in command and control applications. A major emphasis of the DFVLR research activity centers on the evaluation of dynamic allocation strategies for shared satellite channels servicing large numbers of ground stations. The packet satellite technology is one such technique and its performance under a variety of uses and under a variety of conditions will be a major focus of attention for the researchers at DFVLR. This work includes modelling of the scheduling strategies, use of remote measurement of channel conditions as seen by different ground stations, monitoring of system status and the integration of modelling, measurement and feedback control techniques to improve system robustness under hostile conditions.

DFVLR is coupled into the SATNET system by means of a SATNET ground station located at Raisting. A gateway, located at DFVLR in Oberpfaffenhofen, connects a local network complex into SATNET and also provides for planned connectivity into the public DATEX-P packet switching system offered by the German Bundespost.

In addition to their interests in the basic satellite technology, DFVLR has organized a collection of facilities to study the use and performance of the internet system which includes local networks at DFVLR and the German Datex-P public data network. Plans have been laid to carry out experiments with multimedia electronic message

communication for the support of command and control applications of specific interest to the German Ministry of Defense.

NDRE and NTARE

The Norwegian Defense Research Establishment and the Norwegian Telecommunications Administration Research Establishment, located at Kjeller, Norway, are active participants in this cooperative research program. Using a SATNET ground station located at Tanum, Sweden, NTARE and NDRE are connected into the Internet System by means of a gateway at NTARE.

At NDRE, a major concern is the control and use of multiple satellite ground stations for land and maritime use, for which packet satellite technology is well-suited. A considerable amount of effort at NDRE has been aimed at the modelling and measurement of packet satellite performance under a variety of conditions, including the use of ground stations of unequal data capacity in the combined network. NTARE is focusing its attention of the use of the internet technology for the support of voice and data applications, particularly in the context of local data networks which can use packet satellite technology for long-haul interconnection. This is especially important for the support of rapidly deployed land and sea communication systems for command and control applications. NDRE and more recently, NTARE, have engaged in joint demonstrations with the U.S. Naval Electronics Systems Command, of voice/data command and control conferencing across multiple packet networks. In one particular demonstration, a ship at sea in the U.S. Monterrey Bay area was outfitted with a packet radio which connected to the U.S. mainland by way of an airborne packet radio. Traffic from the ship was carried to Norway over the ARPANET and SATNET to a local network at NDRE and several real-time, interactive exchanges were demonstrated to show the viability of the internet technology for command and control. Interactive voice/data demonstrations of this same technology are planned for the near future.

RSRE

The Royal Signals and Radar Establishment, located at Malvern in the UK, has had a long interest in packet communication techniques and, in the course of its research work, has developed a packet switching system which uses a variation of the international X.25 interface standard, modified to address special military concerns (such as precedence, security, and transaction processing). The RSRE Pilot Packet Switching Network (PPSN) is connected into the Internet System by means of

gateways which are located at RSRE and University College London, which in turn connect to the SATNET which is connected by additional gateways into the ARPANET and other U.S. networks.

One of the primary concerns at RSRE is the development of techniques to utilize public data networks as part of the normal networking support for UK Ministry of Defense command and control. To this end, RSRE also has a connection with the UK public Packet Switching Service (PSS) operated by the British Telecommunications Corporation. RSRE is exploring a variety of methods for the interconnection and use of public and private packet networks, including the standard US DoD internet protocols and also translating gateways which allow international standards such as X.28/X.29 to be used to support terminal traffic destined for support computers located in the DoD Internet System.

A major focus of the RSRE effort is security and access control for military data communications. A consequence of this interest has been the development of protocols and architectures which incorporate advanced, end-to-end security technology as an essential component of the internet system. In addition, RSRE has supported initiatives in the development of secure computer systems and technology for the production of trusted software. In the course of their work on end-to-end reliable internet communication protocols, RSRE has made major contributions in the area of flow and congestion control which have been incorporated into the U.S. DoD standard Internet Protocol specifications.

RSRE has engaged in regular experimental use of electronic message system technology, in the context of their private, public and Internet System networking environment, as a means of exploring how to apply this technology to command and control problems faced by the UK Ministry of Defense.

·UCL

University College London under the support of RSRE as well as DARPA, is a primary participant in the cooperative command and control research program. UCL has adapted the Cambridge Ring local network technology to support experiments in distributed processing in the context of multi-media electronic messaging as well as in the context of the interconnection of public and private data networks. A SATNET ground station is located at Goonhilly Downs in the UK and a gateway to it is located at UCL in London. Traffic from UK sites is routed either through the SATNET or through the International Packet Switching Service (IPSS) offered by the British Telecommunications Corporation. Some sites in

the UK have access to the UCL multi-network complex by means of the British Telecom PSS system, as well.

A primary focus of UCL attention has been on the translation of various protocols such as X.25/X/2B/X.29 to and from the DoD Standard Internet Protocols, in addition to the interconnection of local multi-media electronic message systems with similar systems at other sites in the Internet System and in other UK university sites. This work has uncovered many important concepts which must be applied to support the cooperation of independently implemented and managed electronic message systems. Such concepts are important to identify and demonstrate since they represent fundamental mechanisms by which different NATO message systems may be made to interoperate.

Among the important other ares of UCL work are access control techniques for assuring that distinct network or message system jurisdictions can specify and enforce access control policies and also techniques for the integration of facsimile, text and eventually voice and graphics into military command and control systems. In this context, UCL has also been very active in the development and test of national and international standards for data communications.

SUMMARY

This paper has briefly outlined the activities of a number of U.S. and European research organizations which are working jointly and cooperatively to develop and demonstrate a variety of technologies deemed essential for future NATO command and control system interoperability. The primary focus of their attention is on packet switched networking and the development of applications which can take advantage of this highly dynamic and robust technology. It is the mutual objective of these organizations to provide a technical basis on which future and perhaps even existing national and NATO command and control systems can evolve to support an increasingly automated environment and to use public as well as dedicated military computer and communications systems with the assurance that interoperability requirements can be met.